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(54) A multi-band cellular basestation antenna

(57) The present invention relates to a multi-band cellular basestation and in particular relates to antennas for such basestations. There is a growing need for multi-band basestation antennas for mobile communication systems, to serve existing 2nd generation systems, and emerging third generation systems. For example, GSM and DCS1800 systems currently coexist in Europe, and emerging 3rd generation systems (UMTS) will initially have to operate in parallel with these systems. The present invention provides a dual/triple/multi-band performance cellular basestation antenna having a shared aperture, having a first set of radiating elements operable at a first frequency range; a second set of radiating elements operable at a second frequency range; wherein the first set and second set of radiating elements are interleaved.

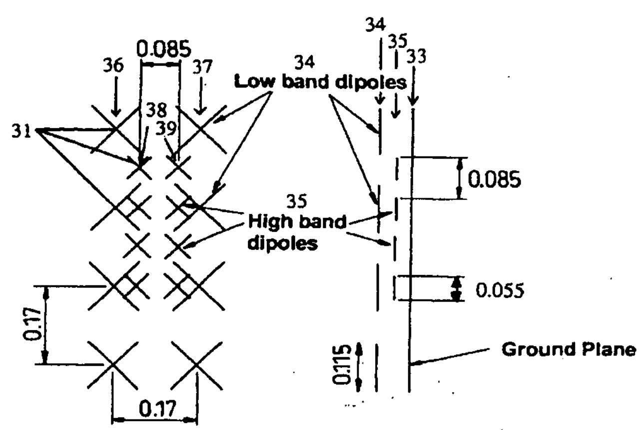

Fig. 3a

Fig. 3b

First embodiment of a dual polarised triband basestation antenna using two radiating layers.

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Description

Field of the Invention

[0001] The present invention relates to a multiband cellular basestation and in particular relates to antennas for such basestations.

Background to the Invention

[0002] There is a growing need for multiband basestation antennas for mobile communication systems, to serve existing 2nd generation systems, and emerging third generation systems. For example, GSM and DCS1800 systems currently coexist in Europe, and emerging 3rd generation systems (UMTS) will initially have to operate in parallel with these systems. At a given base site there may be a need to cover all three bands, and if separate antennas are used for each band this results in an unacceptably large number of antennas. Typically, two antennas are used per sector at a base site, which allows for receive diversity on the uplink. Consequently, for a base site covering all three bands this would result in 6 antennas for an omnidirectional base site, and 18 antennas for a trisector, or tricellular arrangement. The problem is similar in North America where AMPS/NADC, PCS, and 3rd generation systems will have to coexist.

[0003] Some of the frequency bands of interest are shown in Tables 1-3. Table 1 shows the frequency bands of some first and second generation systems. Table 2 shows the IMT-2000 recommendations regarding frequency allocations for third generation systems, along with the actual spectrum availability in Europe. Table 3 shows the spectrum availability in various parts of the world compared to the IMT-2000 recommendations.

[0004] There are a number of issues to consider regarding the basestation antenna. Firstly, it would be preferred that a single structure covering all three frequency bands exists to minimise the number of antennas at any given base site. It would be preferred that the different bands should therefore have a shared aperture. The antenna structure should be designed for ease-of-manufacture and it should also be designed such that the structure has minimum cost. It is possible that antennas of different beamwidths will be required for different cell types (eg. Omni-, trisectored, tricellular, microcell) and so the design should be flexible enough to allow for this. In addition, the number of antennas can be minimised if polarisation diversity is employed rather than space diversity, such that dual polarised antenna configurations need to be considered.

[0005] Some cellular basestation antenna manufacturers have dual frequency band dual polar products, but these comprise colocated separate antennas, the separate antennas being used for the two separate bands and are simply stacked on top of each other, the antennas having been packaged as a single item or placed side by side. Vertically polarised antennas are known for use in the UMTS 1920-2170MHz range, but commercial versions of DCS1800/UMTS cross polar antennas have yet to appear on the market. Large structures, however, are not favoured by town planners and the like: base station structures should be as small and as inconspicuous as possible.

[0006] Basestation antennas are generally array antennas, since these allow flexibility in the control of the radiation pattern. The pattern characteristics can be varied by altering the individual element amplitude and phase weights, which is useful for providing electrical downtilt, and for providing null fill-in. However, arrays are inherently narrowband because the electrical separation distance between elements changes with frequency, and this affects the array performance. In particular, if the element separation becomes too large (electrically) then grating lobes will appear in the pattern, where these are secondary main lobes. These cause a reduction in gain and an increase in the interference in the network (if they appear in the azimuth plane).

[0007] Due to the narrowband characteristics of array antennas, the use of wideband arrays has been very restricted. In the design of a wideband array, the wideband properties of the individual elements, and the wideband characteristics of the array must be considered separately.

[0008] In 'The Three-Dimensional Frequency-Independent Phased Array (3D-FIPA)', J.K.Breakall, IEE Ninth International Conference on Antennas and Propagation, ICAP '95, Conference publication No. 407, pp. 9-11 a design is presented for a three-dimensional frequency-independent phased array (3D-FIPA) which at the IEE ICAP '95 conference. This is achieved by applying a log-periodic principle whereby multilayer dipole arrays are formed that maintain all electrical spacings and heights over a user specified range. The design results in an antenna that maintains nearly constant pattern characteristics, gain, and VSWR (voltage Standing Wave Ratio) over a wide bandwidth. Figure 1 shows top and side views of the form of the array where dual polar elements (crossed dipoles) are employed. The uppermost layer of dipoles are shown emboldened to illustrate the layer that would be excited at the lowest frequency of operation. The 3D-FIPA preserves all spacings and heights above ground (expressed in wavelengths) for active elements as the frequency is varied. However, the ground plane size does not scale with frequency but has a fixed physical size. This will introduce a frequency dependent effect on the antenna performance. In view of the three dimensional nature of the array it may become difficult to manufacture a low cost structure if many dipole layers are required.

[0009] In Wideband Arrays with variable element sizes', D.G.Shively, W.L.Stutzman, IEE Proc., Vol.137, Pt. H, No.4, August 1990 a wideband array structure is presented that operates over a two octave bandwidth. The array consists of large and small cavity-backed

Archimedean spiral elements in alternate positions. The general planar case is a filled grid version of the array shown in Figure 1b.

[0010] The diameter of the large spirals in Figure 1b is twice that of the small spirals. These spiral elements are circularly polarised and radiate when the perimeter of the spiral is approximately one wavelength. Consequently, the maximum spiral perimeter (dictated by the diameter) determines the lowest frequency of operation. As the frequency is increased, the location of the active region of the spiral moves towards the centre of the spiral. However, the aperture size does not scale with frequency, and consequently, the gain and beamwidth of the array do not remain constant with frequency. In fact, the gain increases with frequency as the beamwidth decreases and therefore is not suitable for a multiband basestation antenna.

OBJECT OF THE INVENTION

[0011] The present invention seeks to provide a dual or triple frequency band performance cellular basestation antenna having a shared aperture. The present invention also seeks to provide such an antenna which is of minimum dimensions.

STATEMENT OF THE INVENTION

[0012] In accordance with a first aspect of the invention there is provided a dual band base station antenna comprising:

> a first set of radiating elements operable at a first frequency range having a centre-band wavelength λ_1 and a centre-band frequency f_1;
>
> a second set of radiating elements operable at a second frequency range having a centre-band wavelength λ_2 and a centre-band frequency f_2; and a ground plane;
>
> wherein the centre-band frequency f_1 of the first frequency range is of the order of ¼ - ¾ of the centre-band frequency f_2 of the second frequency range;
>
> wherein the first set of radiating elements is arranged in two columns spaced less than λ_1 apart;
>
> wherein the first and second sets of radiating elements are interleaved, the second set of radiating elements being spaced less than λ_2 apart; and
>
> wherein the first and second sets of radiating elements are spaced apart from the ground plane.

[0013] The frequency bands are determined, typically, by national and supra-national regulations. The provision of a multi-band antenna reduces the size of an antenna structure such as are associated with a cellular communications basestation.

[0014] Preferably the first set of radiating elements are spaced from the ground plane by approximately a quarter of a wavelength at centre-band frequency f_1 and the second set of radiating elements are spaced from the ground plane by approximately a quarter of a wavelength at centre-band frequency f_2.

[0015] The second set of radiating elements can be in the same plane as the first set of radiating elements.

[0016] Preferably the first and second sets of radiating elements are crossed dipoles.

[0017] The radiating elements can also be patches, single dipoles, or other suitable elements.

[0018] Preferably the first and second sets of radiating elements are dual polarised, for example linearly or circularly polarised whereby to provide diversity.

[0019] Preferably the dipoles of the first set of radiating elements are arranged to be greater than one wavelength long, in the frequency range of the second set of radiating elements, and wherein a matching circuit is provided which is arranged to compensate for any inductive reactance in the frequency range of the first set of radiating elements.

[0020] The invention also provides a base station as claimed in claim 9.

[0021] In accordance with another aspect of the invention there is provided a method of operating a dual band base station antenna, said antenna comprising:

> a first set of radiating elements operable at a first frequency range having a centre-band wavelength λ_1 and a centre-band frequency f_1;
>
> a second set of radiating elements operable at a second frequency range having a centre-band wavelength λ_2 and a centre-band frequency f_2;
>
> and a ground plane;
>
> wherein the centre-band frequency f_1 of the first frequency range is of the order of ¼ - ¾ of the centre-band frequency f_2 of the second frequency range;
>
> wherein the first set of radiating elements is arranged in two columns spaced less than λ_1 apart;
>
> wherein the first and second sets of radiating elements are interleaved, the second set of radiating elements being spaced less than λ_2 apart; and
>
> wherein the first and second sets of radiating elements are spaced apart from the ground plane;
>
> wherein, in a transmit mode, the method comprises the steps of feeding signals to either of the first and second sets of radiating elements; and

wherein, in a receive mode, the method comprises the steps of receiving incoming signals using either of the first and second sets of radiating elements.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] In order that the present invention can be more fully understood and to show how the same may be carried into effect, reference shall now be made, by way of example only, to the figures as shown in the accompanying drawing sheets wherein:

Table 1 shows frequency bands for some North American and European mobile communications systems;
Table 2 shows IMT frequency allocation recommendation for third generation systems;
Table 3 shows spectrum availability in various parts of the world;
Table 4 shows the variation with frequency for a wide band element array.
Table 5 shows the array performance for a triangular lattice array.

Figures 1a and b show first and second examples of prior art antennas;
Figure 2 shows a tricellular array with triangular lattice.
Figures 3a and b show a first embodiment of the present invention;
Figures 4a and b show a second embodiment of the present invention;
Figures 5a and b show a third embodiment of the present invention;
Figure 6 shows a fourth embodiment of the present invention;

Graph 1 shows the azimuth radiation pattern for an 8 element array of dipoles in a single column spaced $\lambda/_4$ from a reflector;
Graph 2 shows the azimuth pattern for 2x8 array of dipoles at 1940MHz where the dipoles are arranged in two columns, as in Fig 3a, b.
Graph 3 shows the azimuth pattern for a triangular lattice array at 1940MHz as in Figures 4a and b.
Graph 4 shows the elevation pattern for a triangular lattice array at 1940MHz as in Figures 4a and 4b.
Graph 5 shows an azimuth pattern for a straight (vertical) dipole above an infinite ground plane;
Graph 6 shows an azimuth pattern for an inclined dipole above an infinite ground plane;
Graphs 7 to 9 show the azimuth pattern at 1710, 1940 and 2170MHz for the fourth embodiment;
Graphs 10 to 15 show the azimuth pattern at 880, 920, 960, 1710, 1940, and 2170MHz for a second configuration of the fourth embodiment.

Detailed Description of the Invention

[0023] There will now be described by way of example the best mode contemplated by the inventors for carrying out the invention. In the following description, numerous specific details are set out in order to provide a complete understanding of the present invention. It will be apparent, however, to those skilled in the art that the present invention may be put into practice with variations of the specific.

[0024] For a tricellular arrangement an azimuth 2dB beamwidth of 60° is required, and ideally a 10dB beamwidth of approximately 120° (assuming a path loss exponent n of 3.5), since for a tricellular arrangement, the range to the cell boundary varies with angle. At the ±60° points relative to boresight the range r is half that on boresight. Assuming a $(1/r^n)$ path loss law the difference in path loss is :-

$$10n\log(2r) - 10n\log(r) = 10n\log(2)$$

For n=3.5, which is a typical value for urban environments, 10nlog(2) = 10.5dB.

[0025] Consequently, in this case the antenna 10dB beamwidth needs to be 120° to provide reasonably uniform coverage throughout the cell.

[0026] Typically, GSM basestation antennas have a gain of the order of 16dBi, although lower gain versions are also used where, the gain of these is typically between 13-15dBi. Azimuth 3dB beamwidths are typically 60° - 65°, although some antennas have wider beamwidths of 85°-90°. In many cases two basestation antennas have been used per sector to provide receive space diversity, and each base site would be used to serve three 120° sectors. In this configuration one of the antennas in each sector would be used as the transmit antenna as well as being used as a receive diversity antenna. This requires a diplexer at the base of the mast, and results in base sites with six antennas. Operators today are deploying dual-polarised antennas which means that only three antennas are required per base site, resulting in a much more compact configuration. The dual polarised antenna elements are at ±45°, which has become the industry standard configuration. Downtilt of the main beam of between 0°-8° is used, and the first null is generally filled in, such that it is 16-18dB down on the peak gain. For DCS1800 antennas the specification is essentially the same except that the gain might be 18dBi rather than 16dBi.

[0027] The antennas used in a typical TDMA (IS-136), another 2nd generation system, are broadly similar with the gain similar to DCS1800 at 18dBi. The tilt of the beam varies from 4° uptilt to 12° downtilt. The lower gain antennas that are used vary from 10dBi to 16.5dBi. The azimuth 3dB beamwidths are typically 60°.

[0028] The required operational bandwidth of a three-band antenna in accordance with the invention can con-

veniently be considered as two distinct bands, a lower band in the range 880-960 MHz (8.7%) for GSM and an upper band in the range 1710-2170 MHz (23.7%) for DCS1800 & IMT-2000. The array aperture is scaled for the two bands to preserve the radiation pattern characteristics, and to avoid grating lobes. However, whilst the element spacing must be scaled in the vertical direction to prevent grating lobes, the elevation pattern shape does not need to be preserved. The full height of the low band array can be employed to realise a higher gain in the high band, and a narrower elevation beamwidth.

[0029] Figures 3a and 3b show a first embodiment of the invention with Figure 3a being a plan view of an antenna and Figure 3b being a side view of that antenna. The antenna comprises an upper radiating layer that serves the GSM band, where this consists of crossed dipoles (±45°) 34 on a rectangular grid. The antenna also comprises a lower radiating layer 35 and a ground plane 33 as shown in Figure 3b.

[0030] The lower radiating layer 35 serves the DCS 1800 and the UMTS band. The upper radiating layer comprises a first set of radiating elements labelled low band dipoles 34 in Figures 3a and 3b. The lower radiating layer comprises a second set of radiating elements labelled high band dipoles 35 in Figures 3a and 3b. Both sets of radiating elements are positioned in columns as illustrated in Figures 3a and 3b. For example, the plan view of Figure 3a shows two columns 36, 37 of low band dipoles 34, each comprising four low band dipole radiating elements 34. Two columns 38, 39 of high band dipoles 35 are also shown in Figure 3a.

[0031] The radiating elements 34, 35 operate in a ±45° crossed dipole fashion, following standard manufacturing practice. For the purposes of illustration Figure 3a shows only four elements 34, 35 per column 36, 37, 38, 39, although eight or more elements are used in order to achieve a gain of 16-18dBi. The low band dipole elements of Figures 3a and 3b have a length of about 16.3cm, which corresponds to $\lambda/2$ at 920MHz (centre of the GSM band). Consequently, the vertical and horizontal extent of the tilted dipole is 11.5cm ($16.3/\sqrt{2}$). The vertical and horizontal spacing for the low band elements 34 is set to 17cm, where this corresponds to $\lambda/2$ at 880MHz (bottom of the GSM band). The low band radiating elements 34 are spaced from the ground plane 33 by about 8cm, and this is approximately $\lambda/4$ at 880MHz.

[0032] The radiating layer 35 serving the DCS1800 and the UMTS band is situated below the GSM layer, at a distance of about 4cm from the ground plane 33. The high band radiating dipole elements 35 of this radiating layer are also arranged on a rectangular lattice. The dipole lengths in this case are 7.7cm, which results in a horizontal and vertical extent of the tilted dipoles of 5.5cm. The element spacing in the vertical and horizontal planes is 8.5cm, and this corresponds to 0.48λ at 1710MHz (bottom of DCS1800 band) and 0.62λ at 2170MHz (top of UMTS band).

[0033] If eight elements are used in the vertical direction for each radiating layer 34, 35 then the array length is slightly more than 1.3m (determined by the GSM layer 34). Note that the Figures are not scale drawings and the dimensions given are representative of the actual dimensions for an array with this type of structure. Alternatively, eight elements can be used for the GSM layer 34 and sixteen elements for the high band layer 35. Figure 3 shows the situation where equal beamwidths are provided. It is also possible to use the full height of the antenna to enable more high band elements to be employed.

[0034] The high band array 35 under certain conditions will experience some blocking from the low band array 34. A second embodiment of the invention is shown in Figures 4a and b again with Figure 4a being a plan view of an antenna and Figure 4b being a side view of that antenna. The same reference numerals are used as in Figures 3a and 3b for corresponding features. In this case a triangular lattice as shown in Figure 2 is used for the high band array 35, and the spacing is such that the array aperture for the high band is more sparsely populated as compared with the situation shown in Figure 3. The same number of elements 35 is used as for the low band array 34, but these are distributed in the vertical direction over the same extent as the low band elements 34. Consequently, the high band array aperture is only reduced (scaled) in the azimuth plane. Thus the azimuth pattern is preserved, but the elevation pattern will clearly change, although this does not necessarily represent a problem.

[0035] A computation has been made of the performance of the high band array at 1940MHz with two columns of eight high band elements, and with a separation between the high band columns of $\lambda_{1710}/2$. The high band elements are distributed on a triangular lattice where the vertical separation between elements within a column is λ_{1710} (17.5cm). The offset between the high band columns in the vertical direction is then $\lambda_{1710}/2$ (8.8cm). The computation assumed vertical dipoles spaced $\lambda_{1710}/4$ from a ground plane, and for this case the directivity of the array was computed to be 20.4dBi, and the elevation beamwidth was approximately 6°. However, the azimuth 2dB beamwidth is only 44.7° and the 10dB beamwidth is only 88.4°. This is too narrow for a tricellular arrangement. Other results are shown below, for the case where the horizontal separation between columns is only $0.33\lambda_{1710}$ (0.058m). In this case the performance achieved is well suited for a tricellular arrangement.

[0036] The structure shown in Figures 4a and b can be modified such that both radiating layers 34, 35 are in the same plane. The resulting single radiating layer is placed $\lambda_{880}/4$ above a solid ground plane, and a frequency selective ground plane is then introduced at a distance of $\lambda_{1710}/4$ behind the radiating layer, and such that it sits between the radiating layer and the solid ground plane. The frequency selective ground plane

can comprise an array of crossed dipoles whose feed points are short circuited, which are slightly longer than those present in the radiating layer, and are positioned directly behind each of the high band elements. These then act as reflectors in a similar fashion to a Yagi-Uda array, and are only effective in the high band and not the low band. For the low band the solid ground plane still acts as the reflector. Note that some empirical adjustments may be required to optimise the frequency selective ground plane, where the parameters to be adjusted are the shorted dipole lengths, and the spacing from the radiating layer. Also note that this structure has the same number of layers as those of Figure 3a and b and Figures 4a and b and therefore there is no additional cost associated with having coincident radiating layers.

[0037] Figures 5a and b show a third embodiment which is an example of a situation in which both radiating layers are in the same plane. Figure 5a is a plan view of an antenna and Figure 5b a side view of that antenna. In this case there are three columns of elements 36, 37, 39. The left hand column 36 consists of some triband elements 50 that serve both the low band (GSM) and the high band (DCS1800/UMTS). For operation in the high band this column 36 is combined with the centre column 39, which consists of elements 35 that are resonant in the high band but not the low band. Thus an array of high band elements with a triangular lattice is formed. For low band operation the left hand column of elements 36 is combined with the right hand column 37, which consists of elements 34 that are only resonant in the low band. This structure minimises the number of radiating elements 34, 35 required, but it means that three different element types 34, 35, 50 are being employed. Also, all radiating elements are located on the same layer 51, and so a frequency selective ground screen 52 is employed (if dipole-type elements are used). The frequency selective ground screen 52 is positioned between the radiating layer 51 and a ground plane 53 as described above.

[0038] A feed network for any of the above embodiments is provided as is known in the art, and has several layers. The feed network may be located behind the ground screen 53. For example, the first and second embodiments described above with reference to Figures 3a and b and 4a and b require four separate feed layers, two for each radiating layer to accommodate the two polarisations. The number of ports on the antenna could be either two or four. In the case that four ports are used these are for the low band signals at each polarisation (±45°) and for the high band signals at each polarization (±45°). When two ports are used, the high and low band + 45° signals are combined and output at one port and the high and low band -45° signals combined and output at the other port. If two ports are required to limit the number of coaxial cables running down a mast supporting the antenna, then a diplexer arrangement is integrated into the antenna as is known in the art.

[0039] An array configuration for a fourth embodiment is shown in Figure 6 in which the interleaved arrays of the lower and upper frequencies use two and three columns, respectively, with 0.25 wavelength azimuth spacing and nominal 0.75 wavelength elevation spacing. The elevation spacing can be varied from half of a wavelength to one wavelength.

[0040] The feature of several interleaved or criss crossed columns of low and high band elements, allows the combination of the two upper bands into one band, while maintaining a reasonably constant azimuth beamwidth. The closer spacing of the columns in the resulting array has been found to counteract the narrowing of the azimuth pattern due to the use of slant dipoles. This allows an increase in the elevation spacing from 0.5 to about 0.75 wavelengths, which creates more room for the interleaved elements. The closer azimuth spacing however does not allow two column interleaving for the two bands, hence the three columns for the upper band. The azimuth weighting of the columns, controlled by the number of occupied positions in each column, has changed from 1:1 to 1:2:1. The 1:2:1 tapered aperture has a similar beamwidth to the 1:1 (untapered) two column case.

[0041] The dipoles are half wavelength in length at the centre of each band, approximately 0.16 m and 0.08 m. The elements are each spaced 0.25 wavelengths from the ground plane, i.e. at 0.08 m and 0.04 m respectively. The low band elements effectively ignore the smaller high band elements which are closer to the ground plane than them. However the high band elements are affected by parasitic coupling to the larger low band dipoles which are forward of them. These parasitic excitations perturb the high band azimuth patterns as shown in graphs 7-9, particularly at the lowest part of the upper frequency band (see graph 7). The azimuth beamwidth in this part of the band can be narrow. This problem can be overcome by lengthening the low band dipole, which is counterintuitive, to shift the problem out of band. The low band dipole is now greater than one wavelength long across the upper band, which stops the parasitic effect from narrowing the azimuth beam. The low band dipole is electrically too long, and a matching circuit is required to compensate for any inductive reactance in the low band. The length of the low frequency dipoles can be increased from 0.16 to 0.18m to push parasitic interaction out of the band of interest, as shown in graph 13 which compares with graph 7.

Claims

1. A dual band base station antenna comprising:

   a first set of radiating elements (34) operable at a first frequency range having a centre-band wavelength λ_1 and a centre-band frequency f_1;

a second set of radiating elements (35) operable at a second frequency range having a centre-band wavelength λ_2 and a centre-band frequency f_2;

and a ground plane (33);

characterised in that the centre-band frequency f_1 of the first frequency range is of the order of ¼ - ¾ of the centre-band frequency f_2 of the second frequency range;

wherein the first set of radiating elements (34) is arranged in two columns (36,37) spaced less than λ_1 apart;

wherein the first and second sets of radiating elements (34, 35) are interleaved, the second set of radiating elements (35) being spaced less than λ_2 apart; and

wherein the first and second sets of radiating elements (34,35) are spaced apart from the ground plane (33).

2. An antenna in accordance with claim 1 wherein the first set of radiating elements (34) are spaced from the ground plane (33) by approximately a quarter of a wavelength at centre-band frequency f_1 and wherein the second set of radiating elements (35) are spaced from the ground plane (33) by approximately a quarter of a wavelength at centre-band frequency f_2.

3. An antenna in accordance with claim 1 wherein the second set of radiating elements (35) are in the same plane as the first set of radiating elements (34).

4. An antenna in accordance with any preceding claim wherein the first and second sets of radiating elements (34, 35) are crossed dipoles.

5. An antenna in accordance with any preceding claim wherein the first and second sets of radiating elements (34,35) are dual polarised.

6. An antenna in accordance with any preceding claim wherein the frequency bands are determined by national regulations.

7. An antenna according to any preceding claim wherein the frequency bands comprise three operating bands, two of which are amalgamated.

8. An antenna as claimed in claim 4 wherein the dipoles of the first set of radiating elements (34) are arranged to be greater than one wavelength long, in the frequency range of the second set of radiating elements, and wherein a matching circuit is provided which is arranged to compensate for any inductive reactance in the frequency range of the first set of radiating elements.

9. A base station equipped with an antenna in accordance with any preceding claim.

10. An antenna in accordance with any preceding claim wherein either one or both of the frequency bands comprise two distinct operating-sub bands, wherein the centre-band frequency is the average of the lowest frequency in the lower frequency operating sub band and the highest frequency in the upper frequency operating sub band.

11. A method of operating a dual band antenna, **characterised in that** said antenna comprises:

a first set of radiating elements (34) operable at a first frequency range having a centre-band wavelength λ_1 and a centre-band frequency f_1 ;

a second set of radiating elements (35) operable at a second frequency range having a centre-band wavelength λ_2 and a centre-band frequency f_2;

and a ground plane (33);

wherein the centre-band frequency f_1 of the first frequency range is of the order of ¼-¾ of the centre-band frequency f_2 of the second frequency range;

wherein the first set of radiating elements (34) is arranged in two columns (36, 37) spaced less than λ_1 apart;

wherein the first and second sets of radiating elements (34, 35) are interleaved, the second set of radiating elements (35) being spaced less than λ_2 apart; and

wherein the first and second sets of radiating elements (34, 35) are spaced apart from the ground plane (33);

wherein, in a transmit mode, the method comprises the steps of feeding signals to either of the first and second sets of radiating elements; and

wherein, in a receive mode, the method comprises the steps of receiving incoming signals using either of the first and second sets of radiating elements.

12. A method according to claim 11 wherein the antenna is a cellular communications base station antenna.

13. A method according to claim 11 or claim 12 wherein polarisation is employed as a signal discriminant.

System	
AMPS & NADC (IS-54/136) North America	Rx 869-894 Tx 824-849
PCS North America	Rx 1930-1990 Tx 1850-1910
GSM Europe	Rx 925-960 Tx 880-915
DCS1800 Europe	Rx 1805-1880 Tx 1710-1785

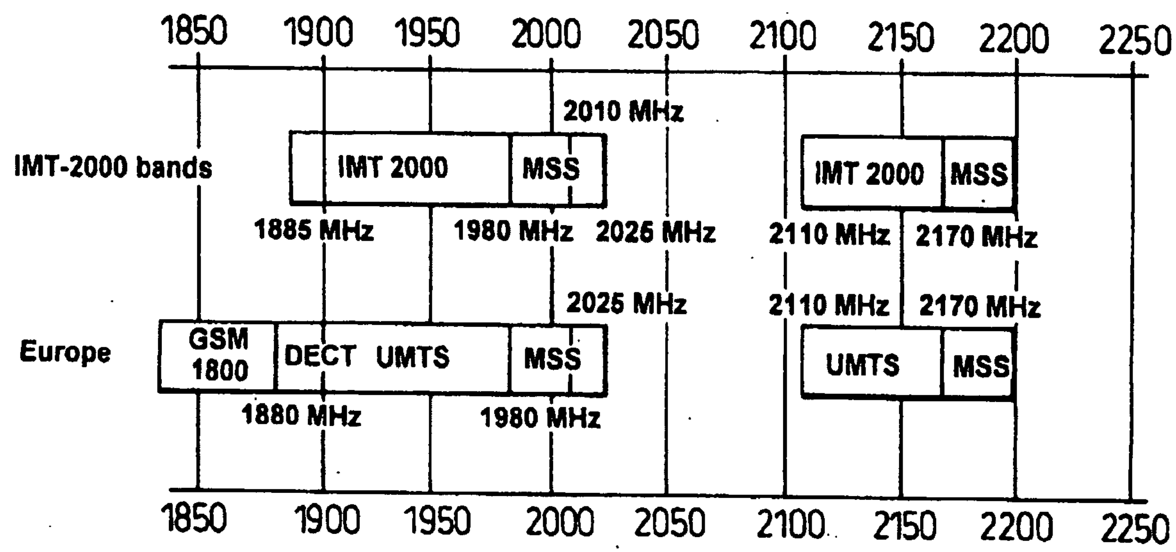
Table 1 – Frequency bands for some North American and European mobile communications systems

PRIOR ART

CEPT ERC Task Group 1 (UMTS)

(1)

Spectrum Requirements, Spectrum Availability



IMT 2000 Workshop

Jersey, Channel Islands
10 – 11 November 1998

Prior Art

Table 2 showing IMT-2000 spectrum allocation, and European spectrum availability

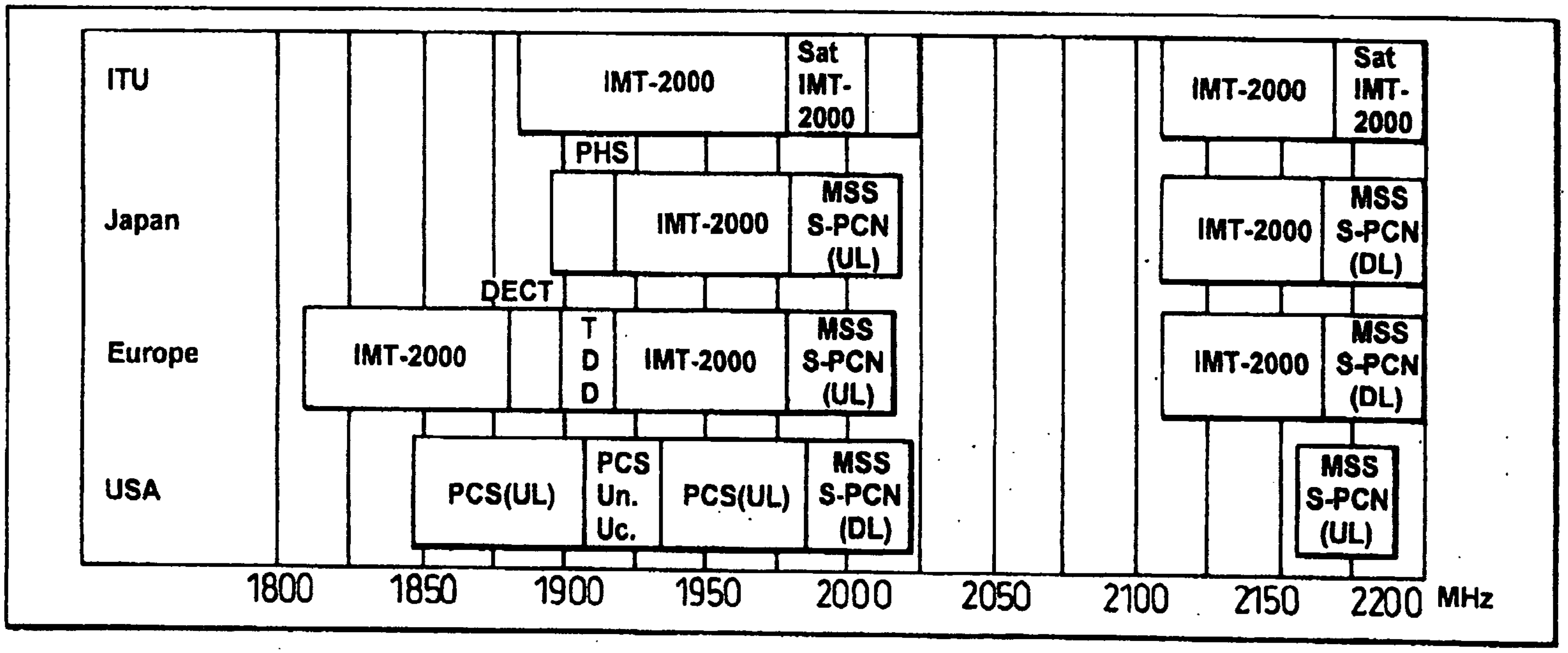


Table 3 – IMT2000 frequency allocations

Prior Art

	1710MHz	1940MHz	2170MHz
Directivity/dBi	15.3	15.5	15.7
Azimuth 3dB beamwidth	112.5°	119.9°	126.8°
Elevation 3dB beamwidth	10.3°	9.1°	7.9°

Table 4 – Trisectored array characteristics: variation with frequency

Frequency/GHz	Directivity/dBi	2dB Azimuth beamwidth (Degrees)	10dB Azimuth beamwidth (Degrees)	Gain at ±60° points relative to boresight dB
1.71	18.5	65.0°	132.1°	-7.9
1.94	19.1	63.1°	127.4°	-8.6
2.17	19.4	61.5°	121.5°	-9.7

Table 5 – Array performance for triangular lattice array

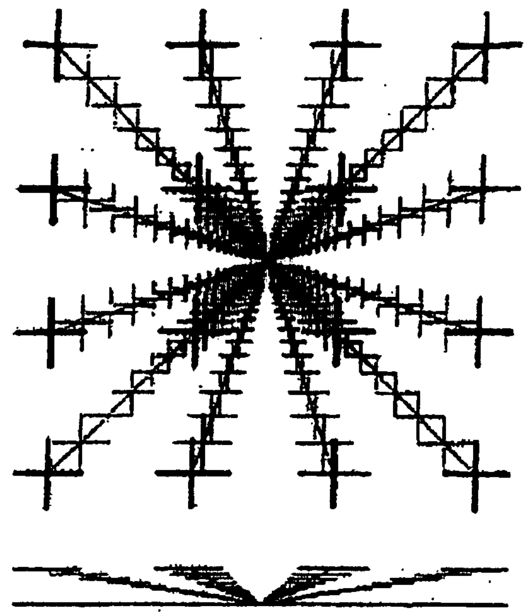


Fig. 1a – 4x4 3D-FIPA (Top and side views)
Prior Art

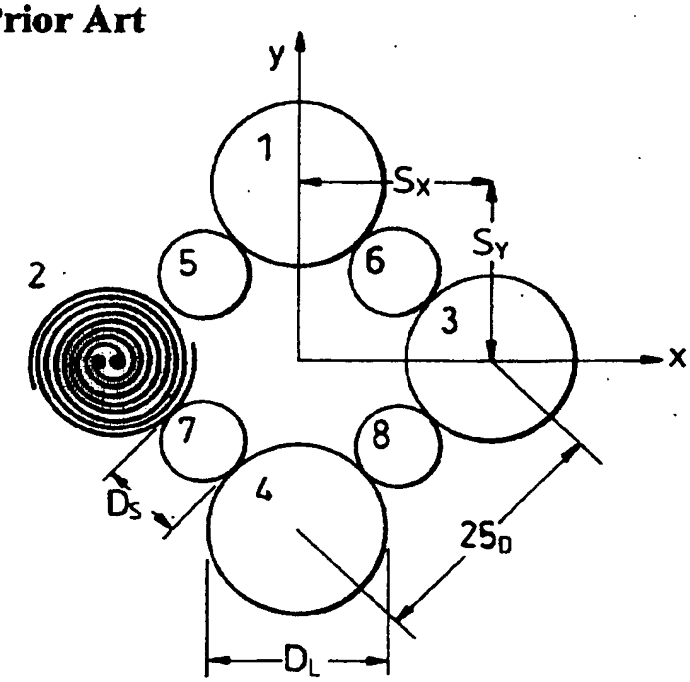


Fig. 1b – Wideband planar array for a two octave bandwidth
Prior Art

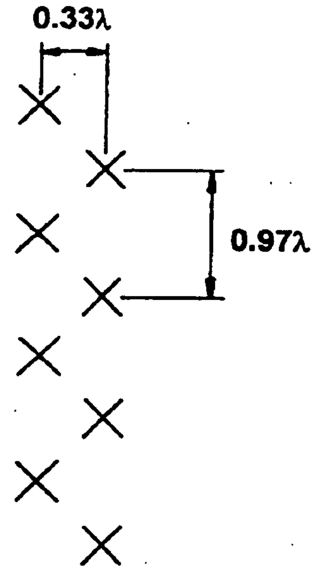


Fig. 2 - Tricellular array – triangular lattice

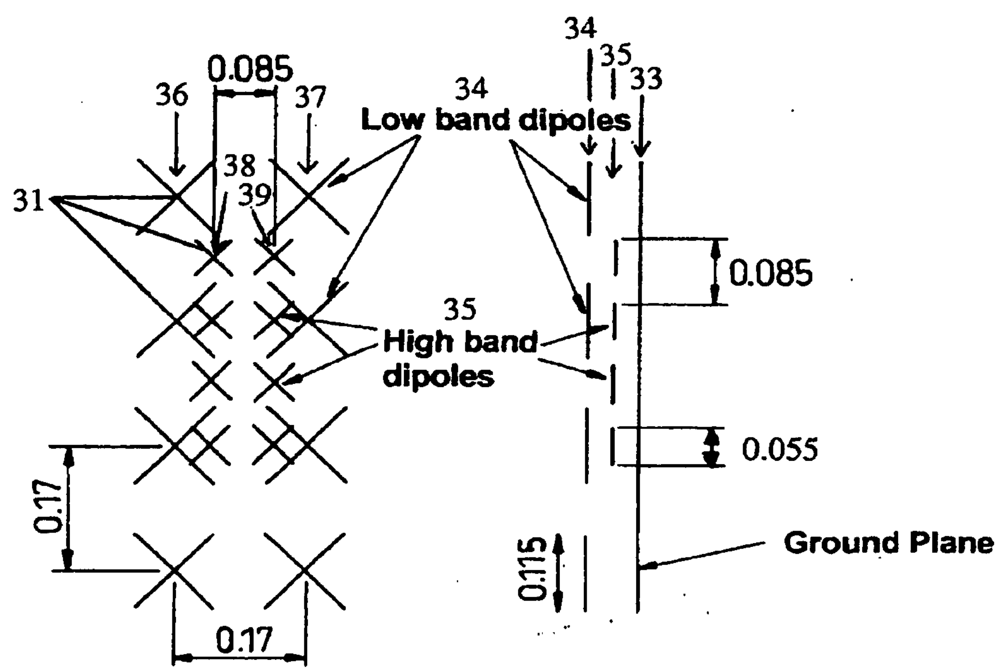


Fig. 3a

Fig. 3b

First embodiment of a dual polarised triband basestation antenna using two radiating layers.

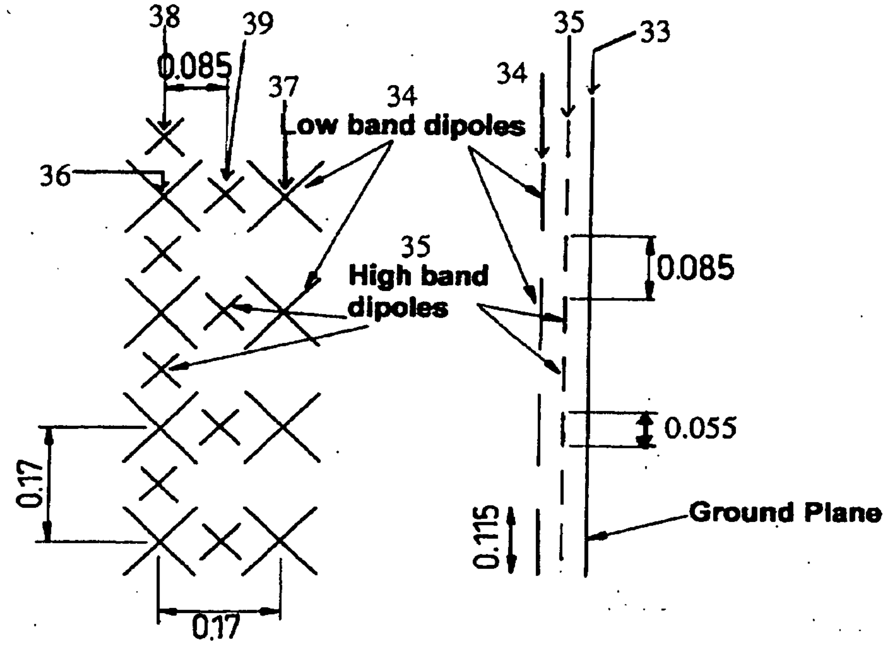


Fig. 4a

Fig. 4b

Second embodiment of a dual polarised triband basestation antenna using two radiating layers – Interleaved high band and low band arrays using a triangular lattice.

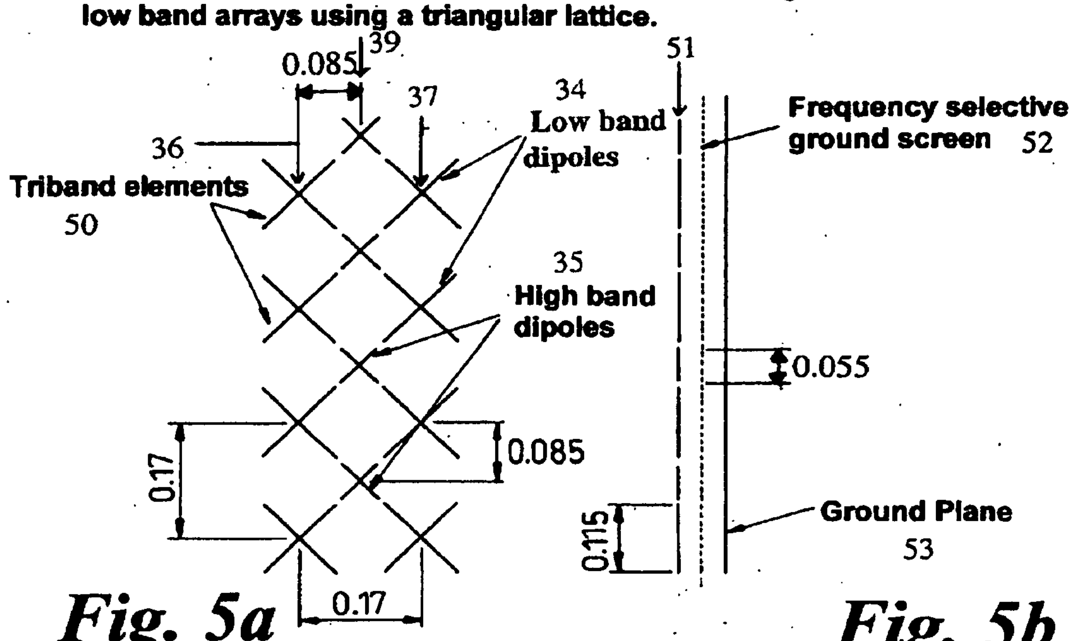
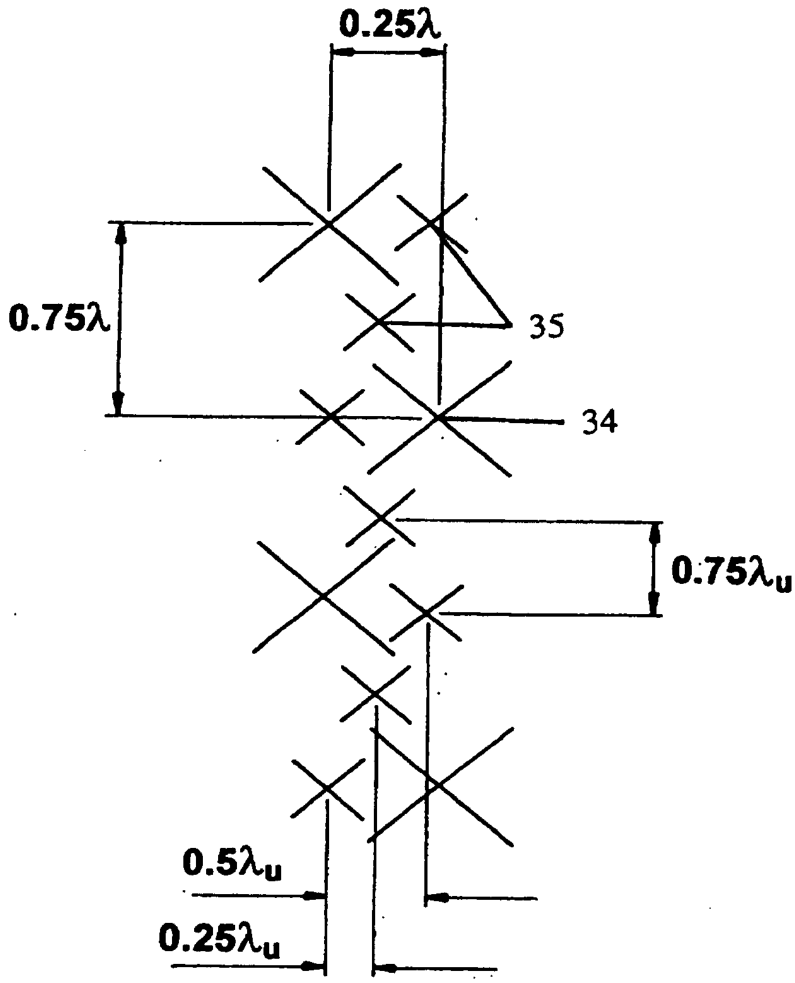


Fig. 5a

Fig. 5b

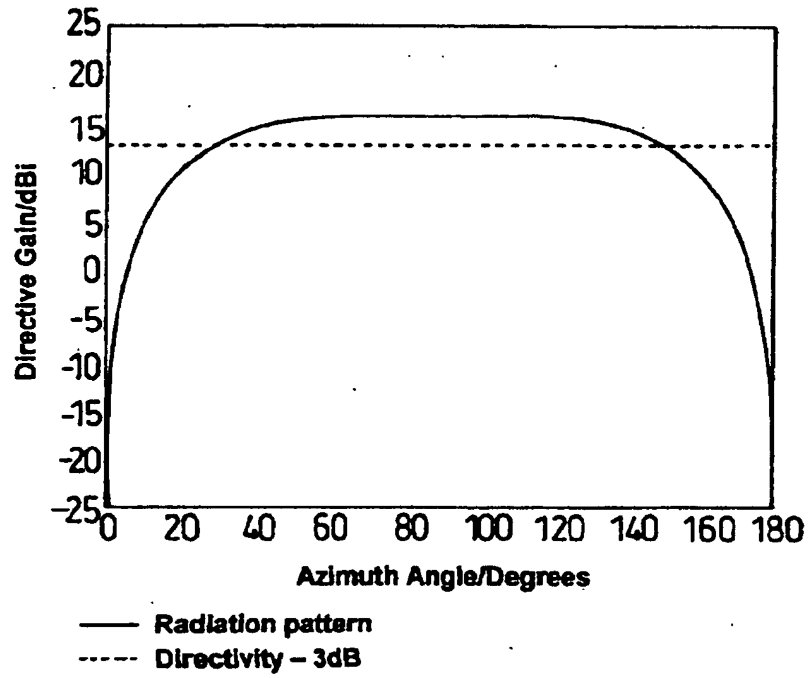
Third embodiment of a dual polarised triband basestation antenna.



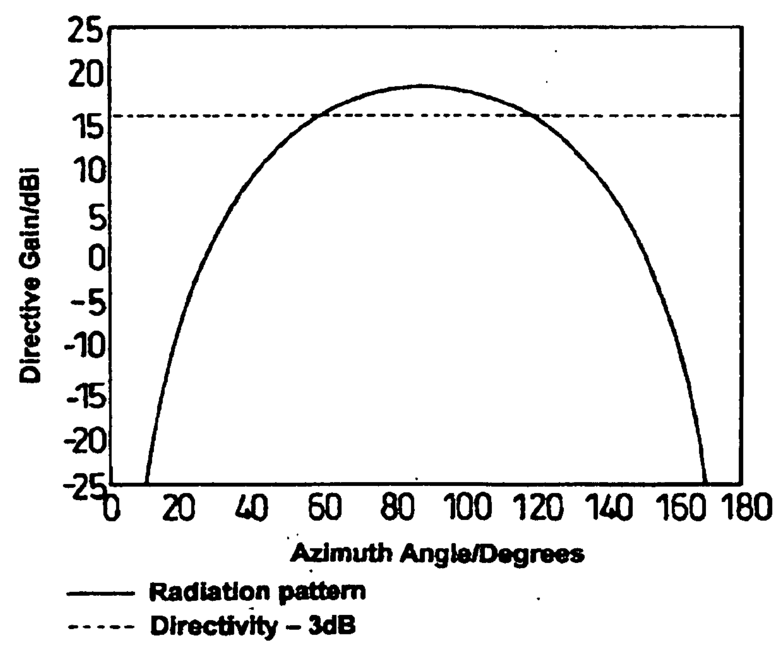
λ = Low frequency wavelength
λ_u = High frequency wavelength

Multiband array with increased vertical element spacing, and high frequency elements staggered at three different horizontal positions.

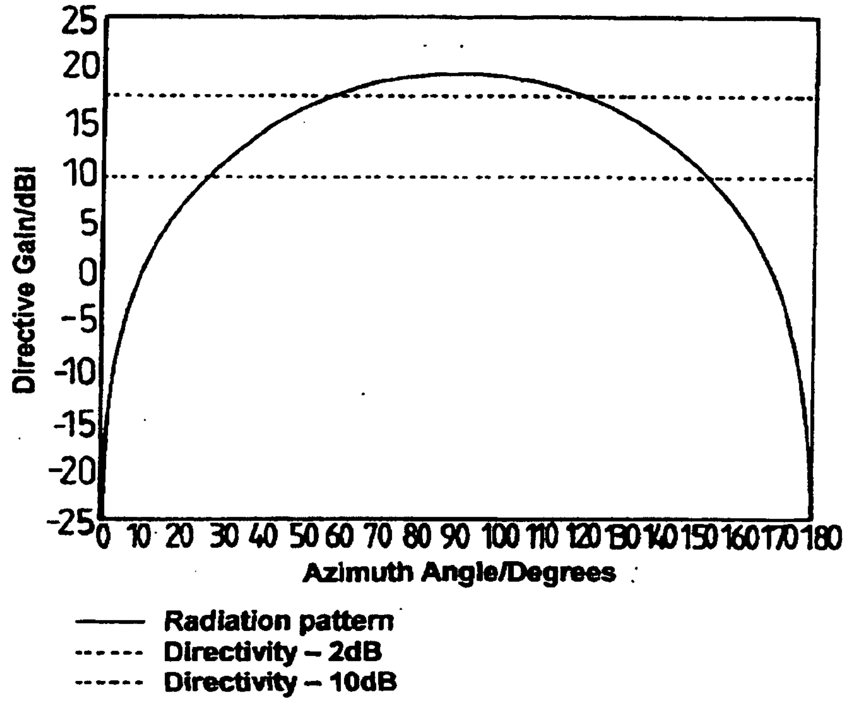
Fig. 6



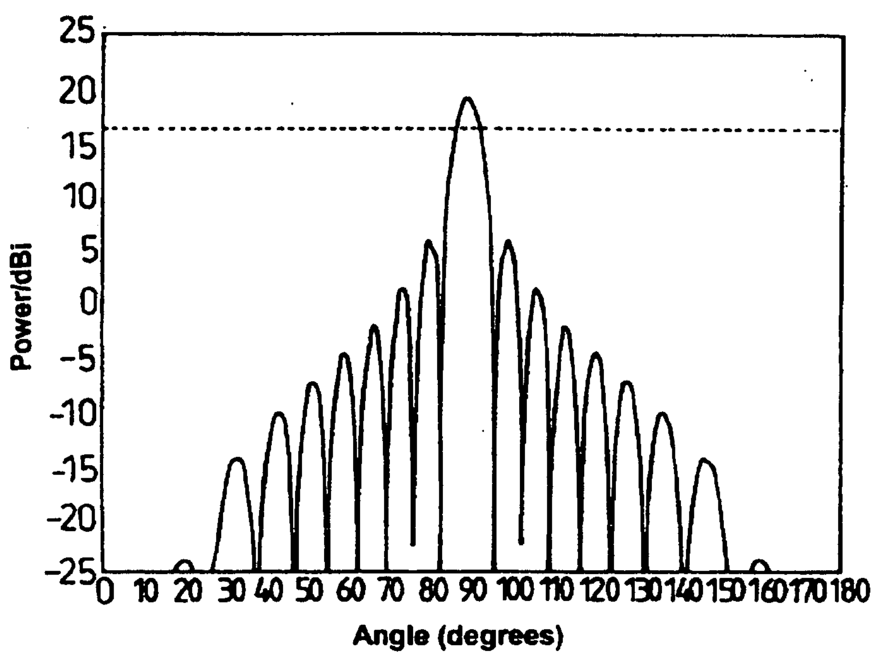
Graph 1 – Azimuth radiation pattern for 8 element array of dipoles spaced λ/4 from a reflector



Graph 2 – Azimuth pattern for 2x8 array of dipoles at 1940MHz

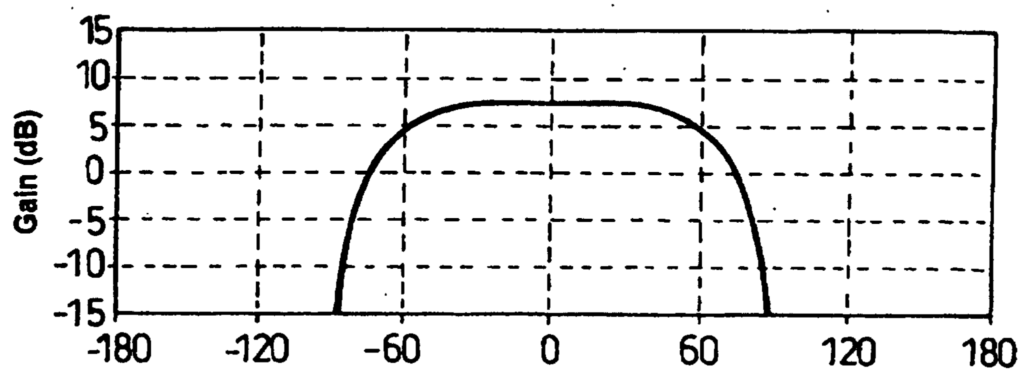


Graph 3 – Azimuth pattern of triangular lattice array at 1940MHz



Graph 4 – Elevation pattern of triangular lattice array at 1940MHz

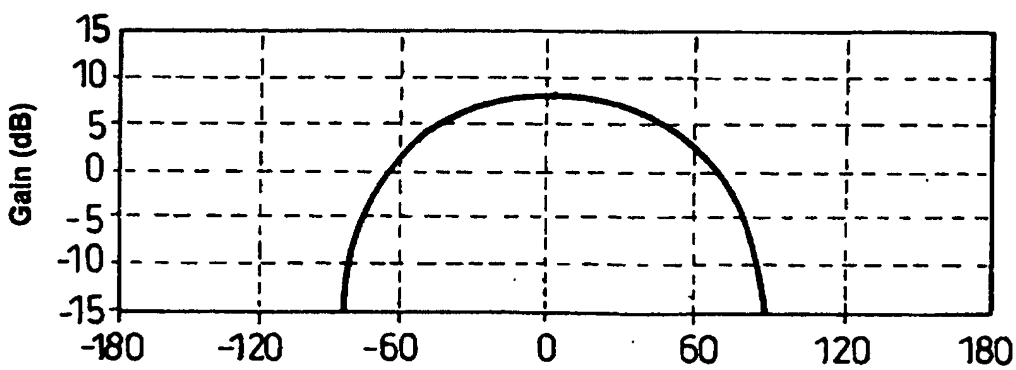
Straight dipole. Azimuth, 1940 MHz. Gain 7.46. 3dB bw 122 degrees.



Angle (degrees)

Graph 5: Azimuth pattern for a straight dipole above an infinite ground plane.

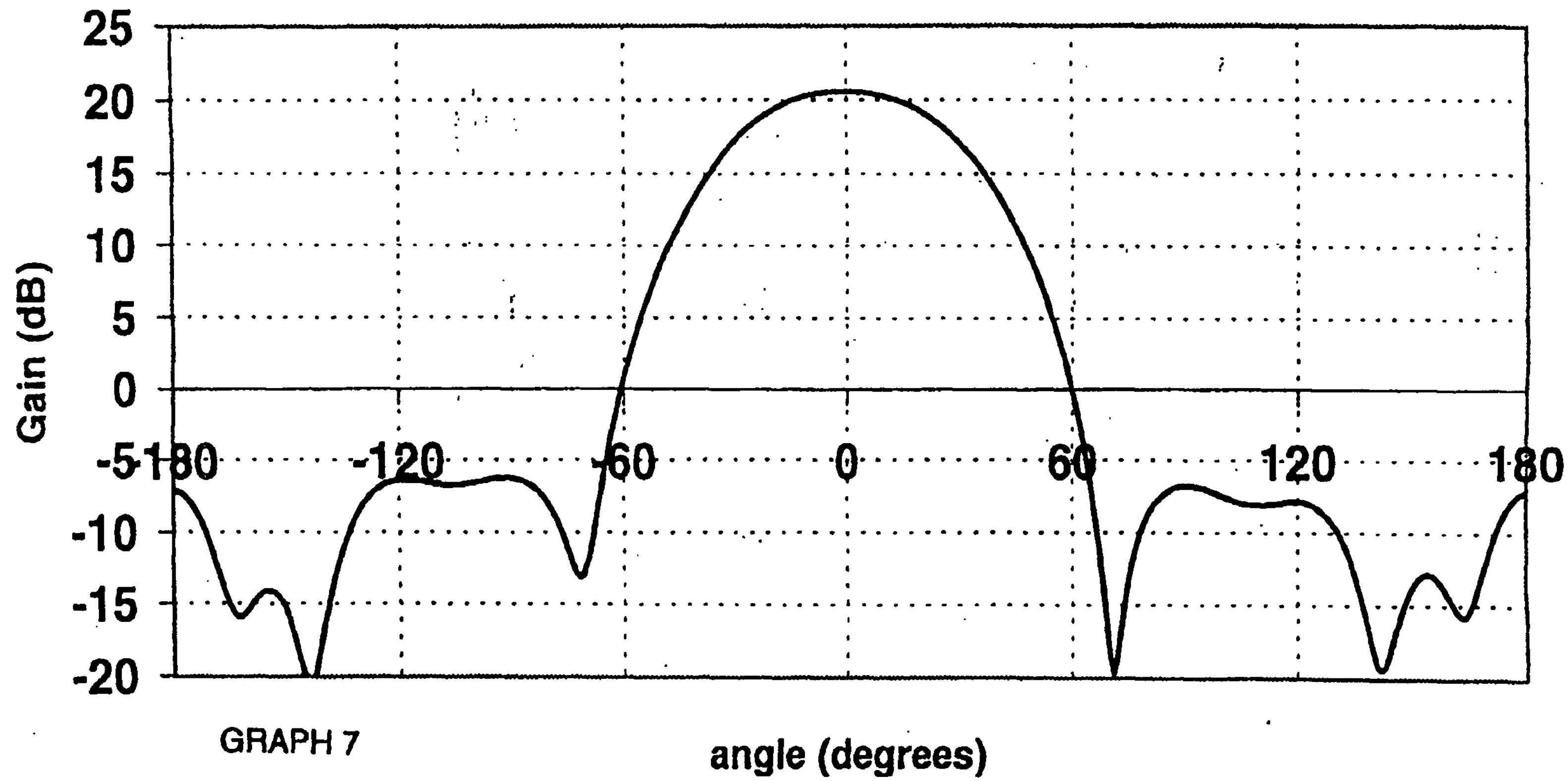
Inclined dipole. Azimuth, 1940 MHz. Gain 7.61. 3dB bw 92 degrees.



Angle (degrees)

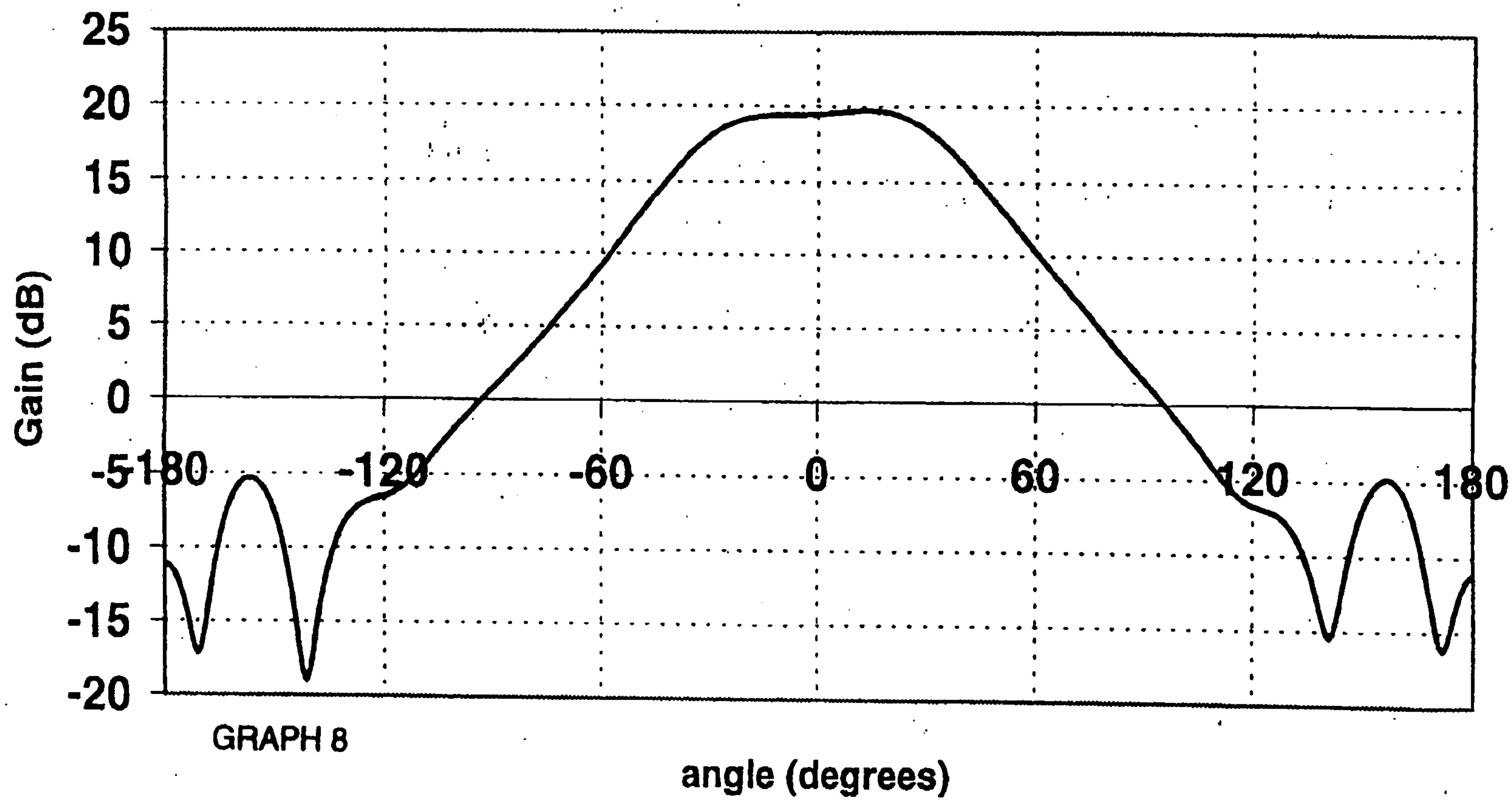
Graph 6: Azimuth pattern for an inclined dipole above an infinite ground plane.

High and low frequency elements. Finite ground plane. Second configuration (0.75wavelength vertical spacing). Azimuth, 1710 MHz. Gain 20.64. 2dB bw 47.5 deg., 3dB bw 56.5 deg., 10dB bw 92.5 deg..



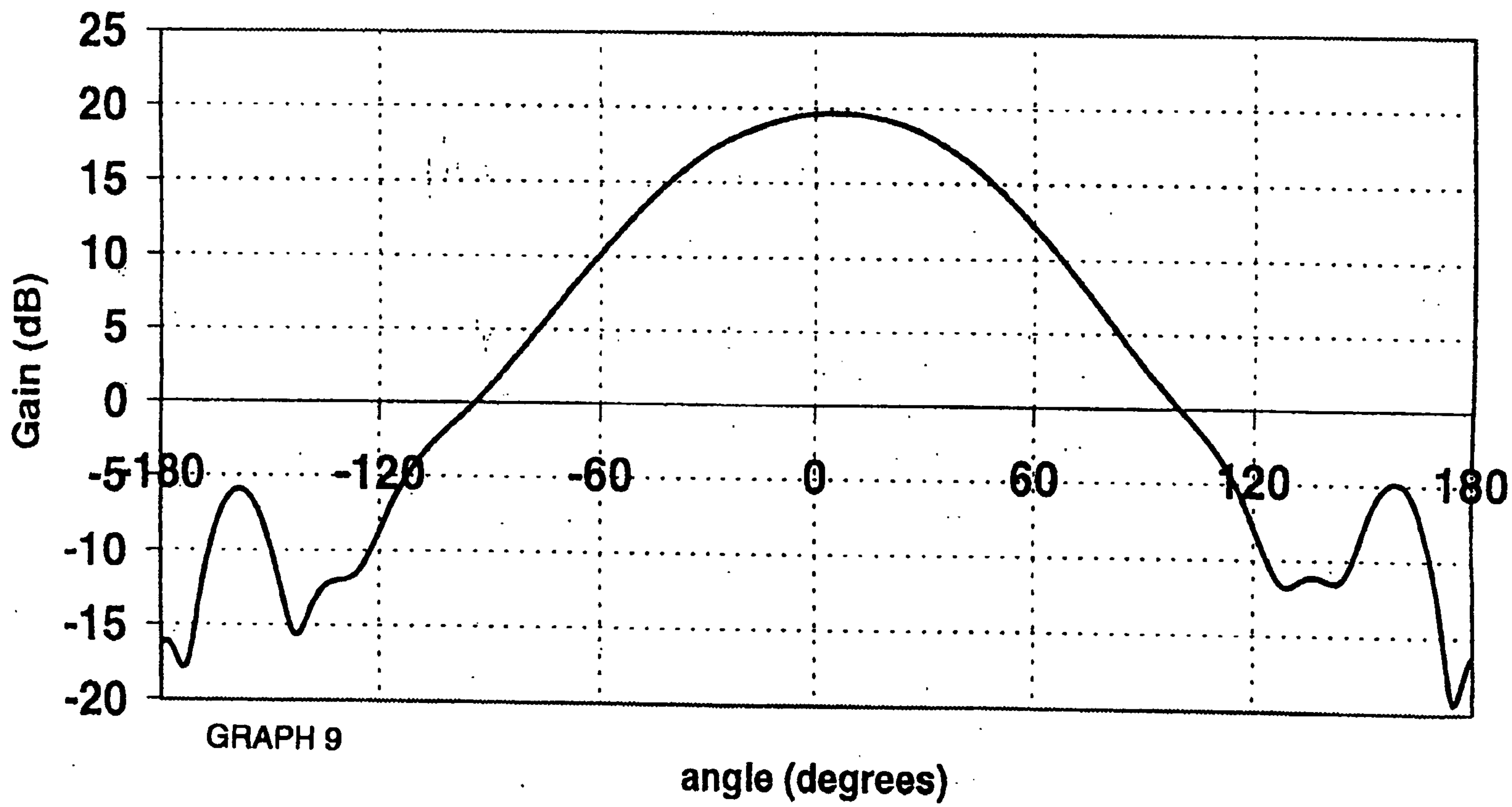
GRAPH 7

High and low frequency elements. Finite ground plane. Second configuration (0.75 wavelength vertical spacing). Azimuth, 1940 MHz. Gain 19.72. 2dB bw 63.5 deg., 3dB bw 73.5 deg., 10dB bw 119.5 deg..



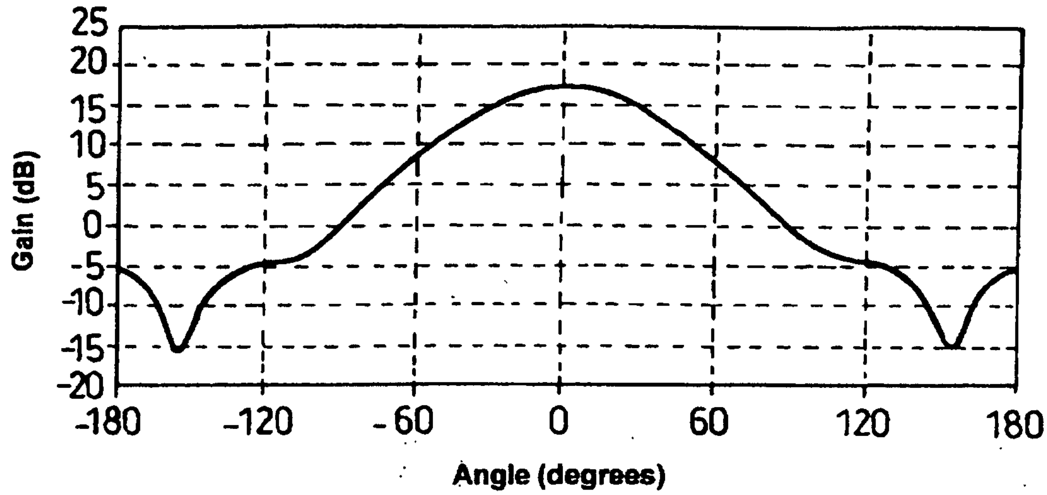
GRAPH 8

High and low frequency elements. Finite ground plane. Second configuration (0.75 wavelength vertical spacing). Azimuth, 2170 MHz. Gain 19.64. 2dB bw 60 deg., 3dB bw 72.5 deg., 10dB bw 130.5 deg..



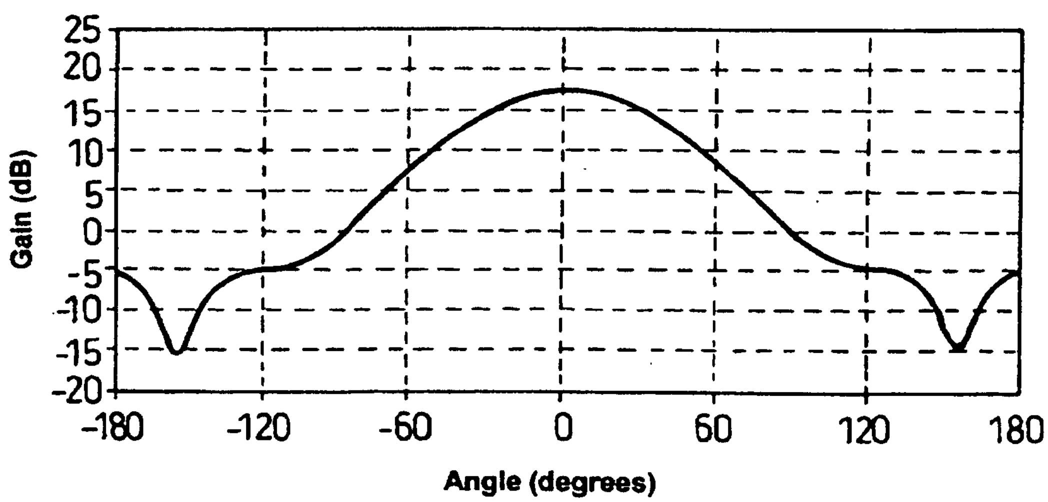
GRAPH 9

High and low frequency elements. Azimuth, 880MHz. Gain 17.2.
2dB beam width 52.5°, 3dB beam width 64.5°, 10dB beam width 125°.



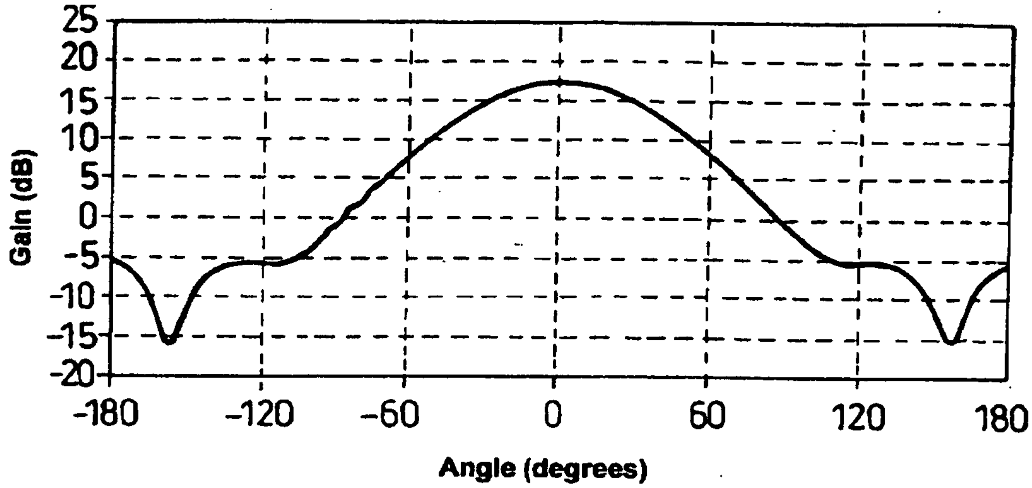
Graph 10

High and low frequency elements. Azimuth, 920MHz. Gain 17.31.
2dB beam width 51.5°, 3dB beam width 64.5°, 10dB beam width 123°.



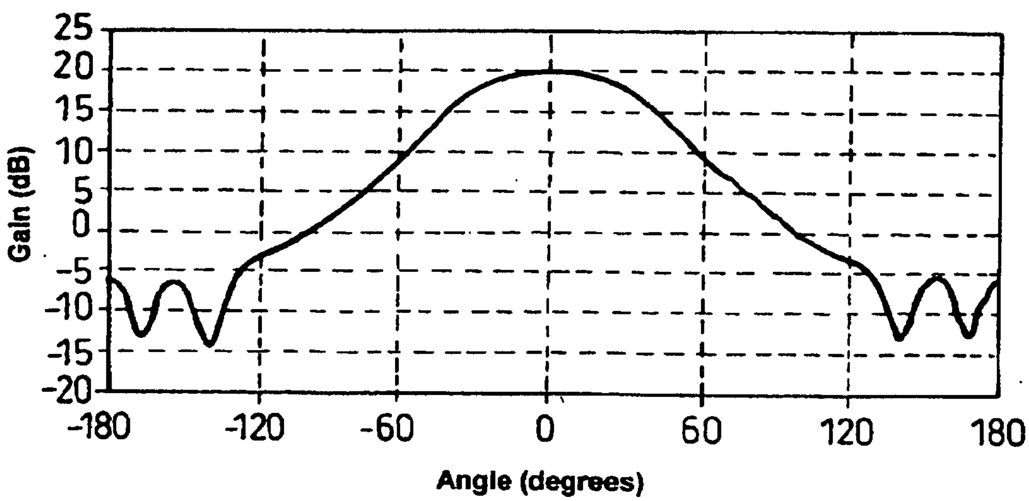
Graph 11

High and low frequency elements. Azimuth, 960MHz. Gain 17.35. 2dB beam width 51°, 3dB beam width 63°, 10dB beam width 121.5°.



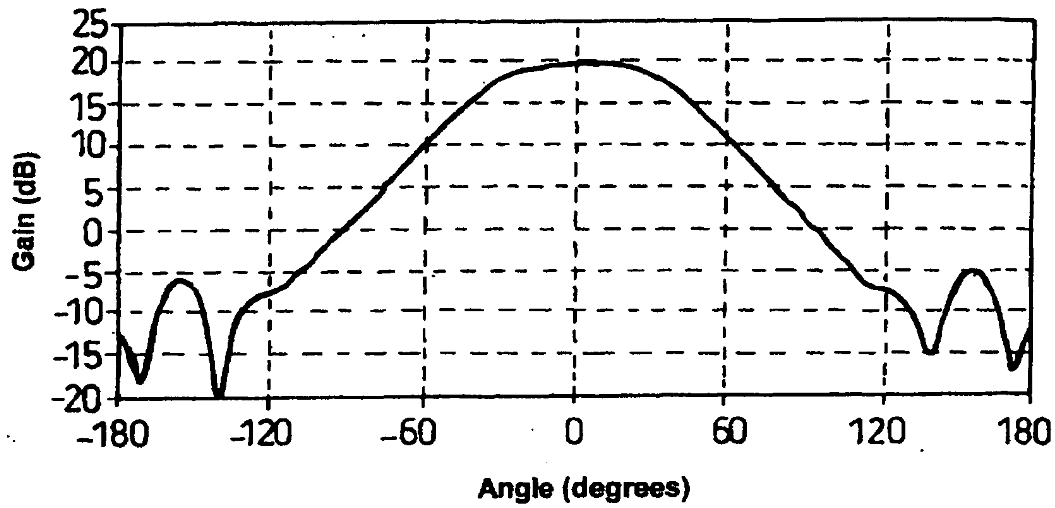
Graph 12

High and low frequency elements. Azimuth, 1710MHz. Gain 19.72. 2dB beam width 59.5°, 3dB beam width 69°, 10dB beam width 117°.



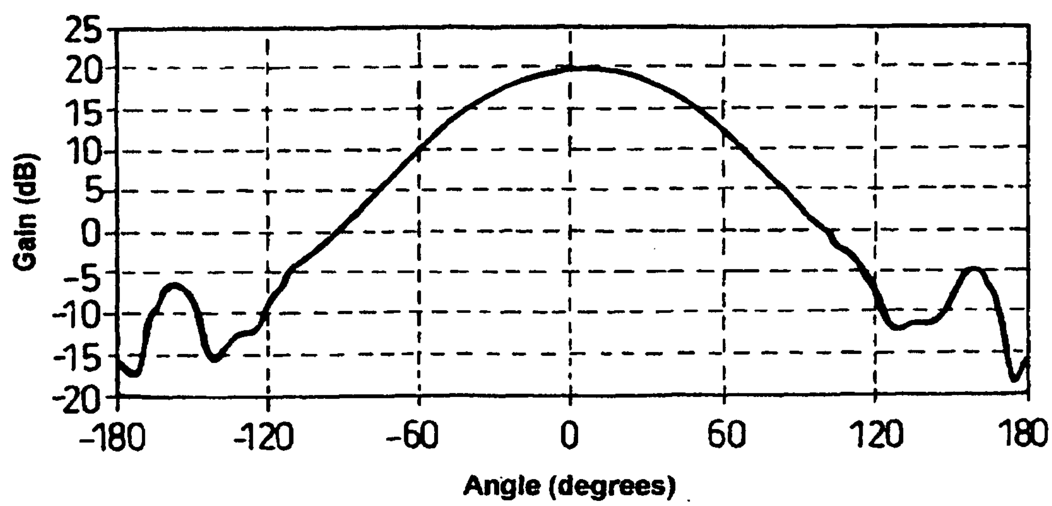
Graph 13

High and low frequency elements. Azimuth, 1940MHz. Gain 19.7.
2dB beam width 66°, 3dB beam width 75.5°, 10dB beam width 123.5°.



Graph 14

High and low frequency elements. Azimuth, 2170MHz. Gain 19.74.
2dB beam width 59°, 3dB beam width 72.5°, 10dB beam width 129.5°.



Graph 15